Landing Site Imaging and Characterization

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First Landing Site Workshop for
2020 Mars Rover Mission

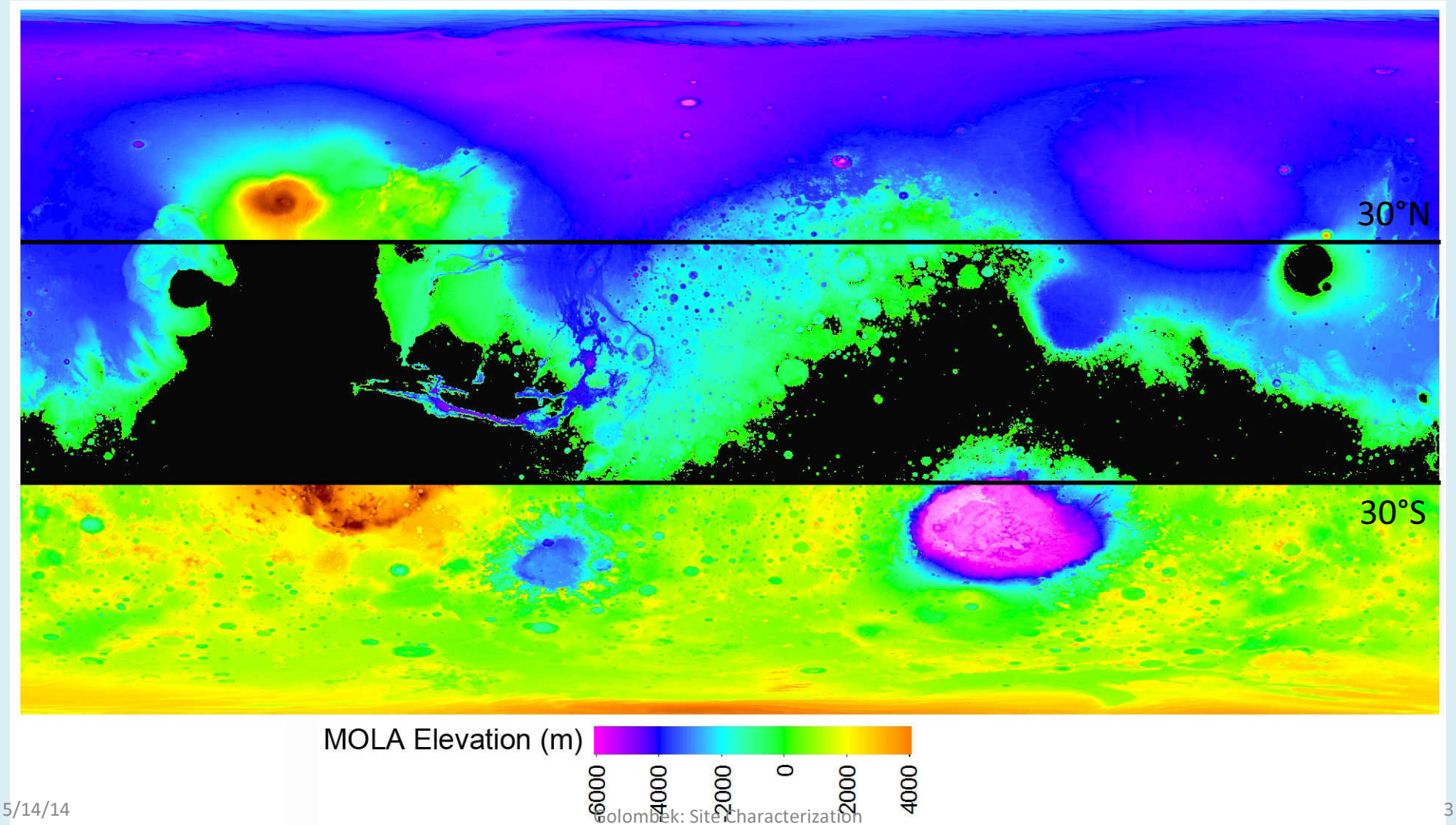
May 14, 2014
Crystal City Marriott
Arlington, VA

Outline

- Where Can 2020 Land?
  - Translate Engineering Constraints to Mars
  - Elevation, Latitude, Dust (Thermal Inertia, Dust Index)
- Imaging Coverage of Landing Sites
  - Lots of Landing Sites have Coverage –
    - How many? how much?
- Characterization of Landing Sites
  - How Many Sites Have Been Characterized? To What Level?
  - Hazard Maps – Is TRN Required?
    - Relief <100 m within 1 km
- What Required to Certify Landing Sites – MSL Example
  - Nearly Complete Stereo CTX and HiRISE Coverage - DEMs
  - Slope, Rock & Material Property Maps
    - Traversability Maps, Inescapable Hazard Maps
  - Radar Reflectivity

Elevation/Latitude Mask

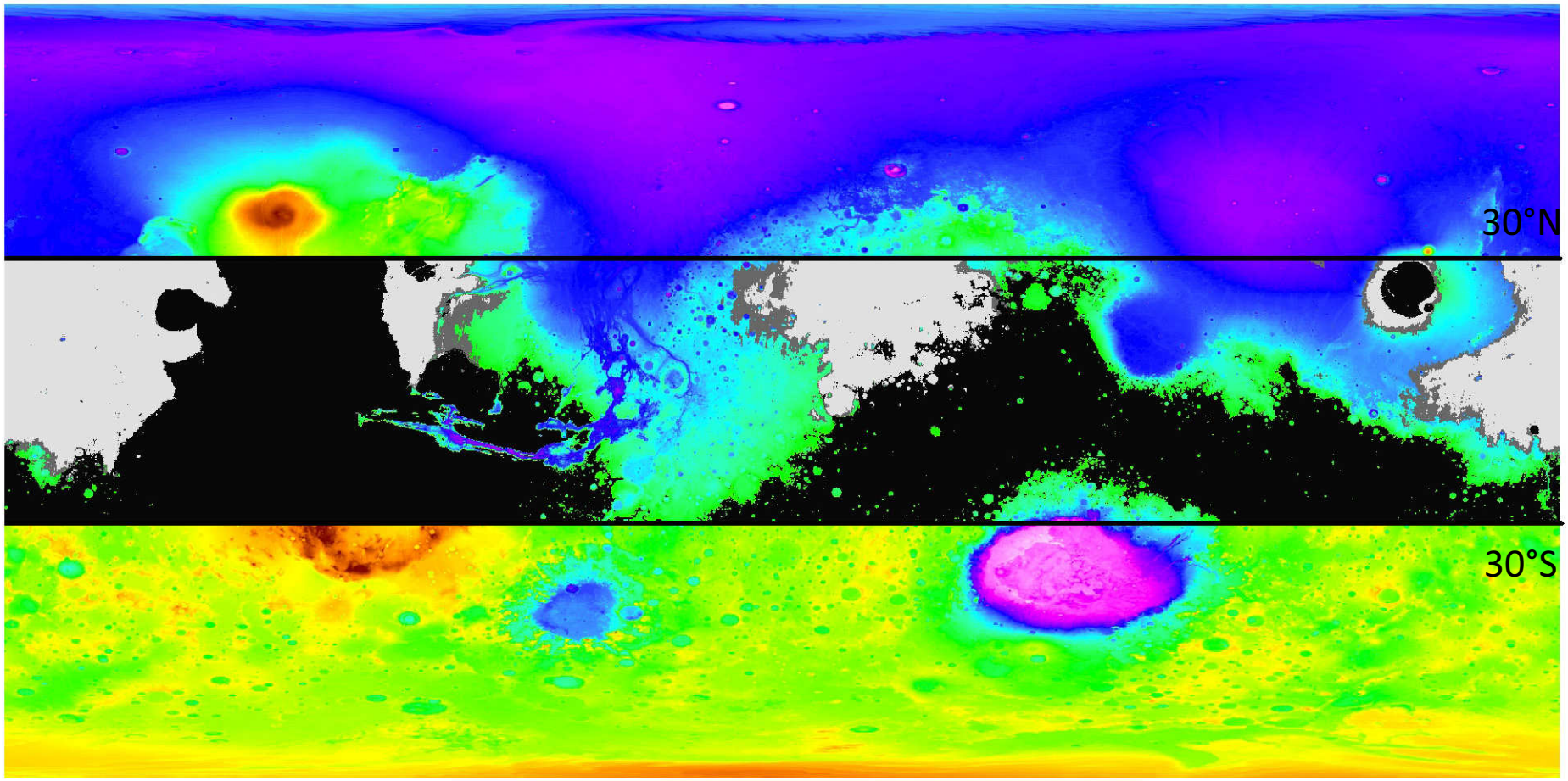
- < +0.5 km [black >+0.5 km]
- ±30°



Elevation/Lat. Mask with Thermal Inertia

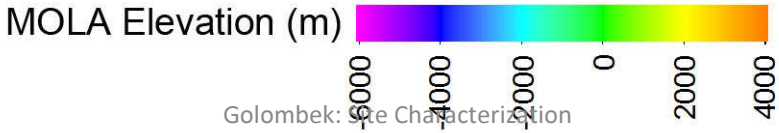
±30° Latitude – About Half Surface Area of Planet

About 2/3 Too High or Too Dusty – Left with Around 15%



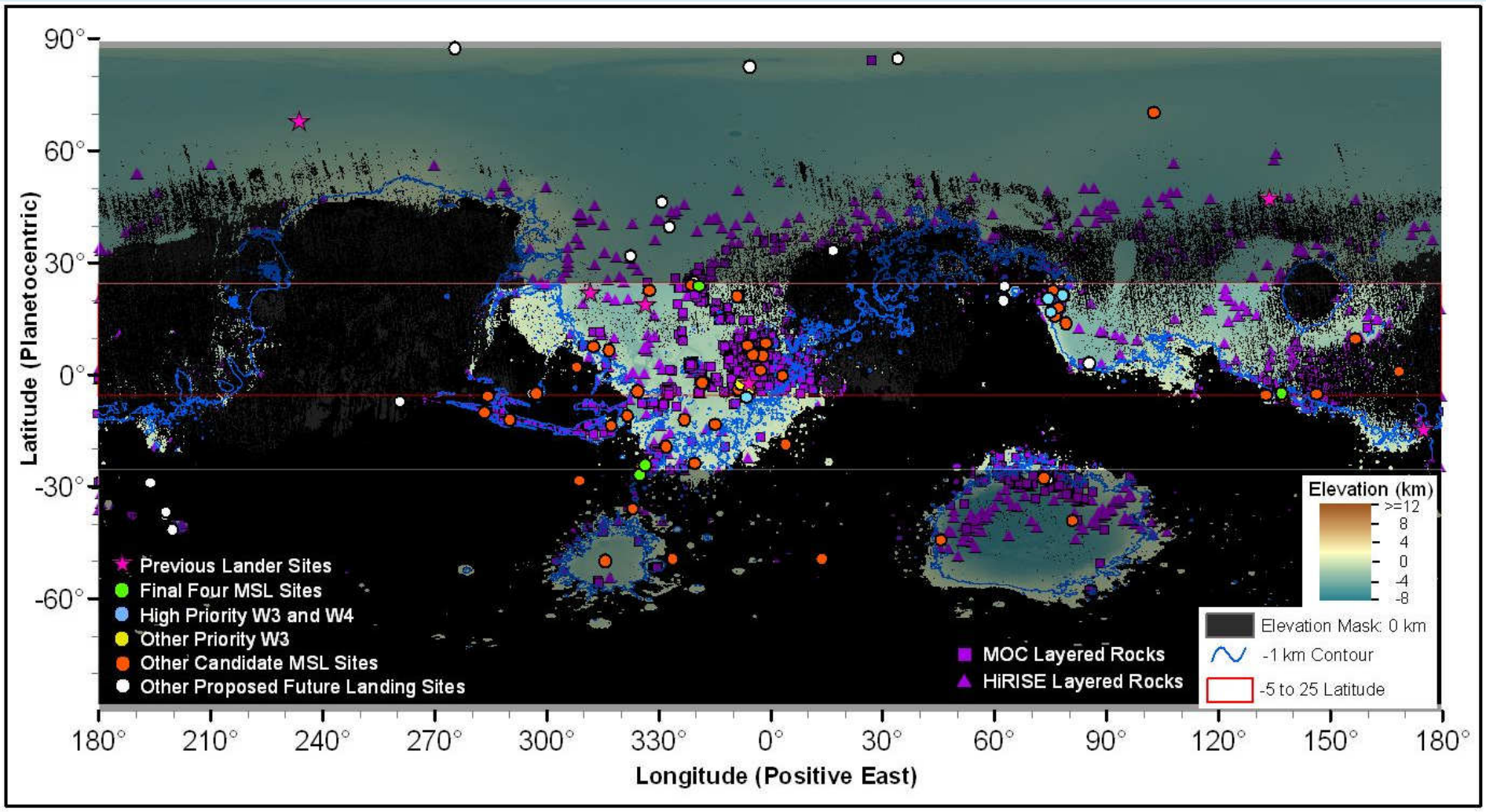
< 150 = dark gray

< 100 = light gray



Christensen et al. (2001)
TES

Lots of Available Sites



±30°, below -1-0 km elevation TI>100; dust index >0.94 (dustier than VL2)
Layered Deposits and Sedimentary Rocks: Malin, Griffes & Stack

Imaging and Characterization of Landing Sites

"Think Like an Engineer"

Landing Sites (1)

Ellipses Based on Image Coverage and Characterization

Site Name, Lat., long, (+E), MOLA elevation	Origin	2020 Interest	Image Coverage, %	Certification, Characterization Status	TRN to Land Safely	TRN Enable Land On	Comments
Final Four MSL Sites							
Gale Crater 4.5°S, 137.4°E -4.4 km	MSL	M, Layered smectites & sulfates, No obvious volcanics	~100% HiRISE DEMs	Certified for MSL	N	Y	MSL Landed Safely, Go To Mt. Sharp
Holden Crater 26.4°S, 325.2°E -2.1 km	MSL, 2020 SDT	H, Layered phyllosilicates, megabreccia	85% HiRISE DEMs	Certified for MSL	N	Probably	Go To south to exposed layers in canyons
Eberswalde Crater 23.9°S, 326.7°E -1.4 km	MSL	M, Delta, clays in bottomset beds, Limited diversity, No volcanics	94% HiRISE DEMs	Certified for MSL	N	Probably	Partial Go To site to get to delta edge
Mawrth 2 24.0°N, 341.0°E -2.2 km	MSL	M, High phyllosilicate concentration Noachian deposits, No obvious volcanics	95% HiRISE DEMs	Certified for MSL	N	N, Non Go To	
Evaluated during MSL or e2e							
Nili Fossae 21.0°N, 74.5°E -0.6 km	MSL, e2e, 2020 SDT	H, clays in Fossae walls & ejecta in ellipse	>80% stereo HiRISE, 2/12	Prelim-Intermediate	Y	N	Dropped after 3rd Workshop, High elevation, May need THA
NE Syrtis 16.7°N, 76.9°E -2.6 km	MSL, e2e, 2020 SDT	very H, strong evidence for aqueous environment, phyllosilicate, carbonate deposits, has Syrtis volcanics	>95% stereo HiRISE, 2/12	Prelim-Intermediate	Y	N, Non Go To	Considered in detail at 2nd Call for New Sites, Not selected, steep sided mesas in ellipse
E Margaritifer 5.6°S, 353.5°E -1.2 km	MSL, e2e, 2020 SDT	H, Chloride & phyllosilicate deposits, No obvious volcanics	>90% stereo HiRISE, 2/12	Prelim-Intermediate	Y	N, Non Go To	Considered in detail at 2nd Call for New Sites, Not selected, extensive large ripples-inescapable hazards

Landing Sites (2)

Evaluated during MSL or e2e							

Jezero Crater 18.4°N, 77.6°E -2.7 km	MSL, e2e, CDP VII, 2020 SDT	H, Phyllosilicate deposits in delta deposits, floor may be volcanic	~90% stereo HiRISE, 2/12	Preliminary	N	Possibly	High Rock Abundance, Could land with THA, maybe possible with TRN (avoid high rock abundance areas?)
Mawrth 0 24.6°N, 338.9°E -3.0 km	e2e	M, High phyllosilicate concentration Noachian deposits, No obvious volcanics	~90% stereo HiRISE, 2/12	Preliminary	N	N	Non Go To site
Ismenius Cavus 33.8°N, 17.2°E -3.5 km	e2e	L, Outside Latitude Band, Smectites in possible glacial lake	>50% stereo HiRISE, 2/12	Preliminary	NE	NE	>30°N Latitude
Gusev, Columbia Hills 14.5°S, 175.5°E -1.9 km	MER, e2e	H, hydrothermal deposits explored by Spirit, cratered plains are relatively unaltered lava flows	~90% HiRISE DEM Columbia Hills, 2/12	Cratered plains and Columbia Hills well characterized by Spirit	N	N, Can land on Columbia Hills w/o	MER landed safely, Non Go To Ellipse on Columbia Hills
Nili Carbonate 21.7°N, 78.8°E, -1.5 km	MSL, CDP VII	H, Carbonates, No obvious volcanics	~90% stereo HiRISE	v preliminary 12/11/09	Y	N, Non Go To	2nd Call for New Sites, Not selected, extensive large ripples-inescapable hazards

Landing Sites (3)

Very preliminary evaluation during MSL							
Melas Chasma 9.8°S, 283.6°E -1.9 km	MSL, CDP V, 2020 SDT	H, valley networks & paleolake with layered sulfate deposits on ledge in Valles Marineris	~80% HiRISE DEMs, 2/12	NE			2nd MSL Wkshp, dropped-25 km circle/ellipse overlaps steep canyon walls, Smaller ellipse seems to fit, Mostly Non Go To
Miyamoto Crater 3.3°S, 352.3°E -1.8 km	MSL	M/L, Phyllosilicates, Meridiani sulfates, inverted channels	Some HiRISE	v preliminary	N	N, Non Go To	Dropped after 3rd Wkshp
N Meridiani 1.6°S, 357.5°E -1.3 km	MSL	M/L, safe site, Meridiani sulfates, Go To layered rocks N of ellipse	Some HiRISE	v preliminary	N	NE	Replaced by S Meridiani after 1st Call for New Sites
S Meridiani 3.1°S, 354.6°E -1.6 km	MSL	M/L, safe site, Meridiani sulfates, Go To phyllosilicates in highlands to S	Some HiRISE	v preliminary	N	NE	Replaced N Meridiani after 1st Call for New Sites, Dropped after 3rd Wkshp, other sites judged safe
Terby Crater 27.4°S, 73.4°E -0.6 km	MSL, CDP V	M, Layered phyllosilicates, Go To layered Rocks to N	~20% mono HiRISE	NE	NE	NE	2nd MSL Wkshp, dropped at 3rd
Mawrth 1 24.6°N, 340.1°E -3.1 km	MSL	M, High phyllosilicate concentration Noachian deposits, No obvious volcanics	~70% stereo, 20% mono HiRISE	v preliminary	N	N, Non Go To	Dropped in favor of Mawrth 2 after 3rd Wkshp
Mawrth 3 23.2°N, 342.4°E -2.2 km	MSL	M, High phyllosilicate concentration Noachian deposits, No obvious volcanics	~65% stereo, 30% mono HiRISE	v preliminary	N	N, Non Go To	Dropped in favor of Mawrth 2 after 3rd Wkshp
Mawrth 4 24.9°N, 339.4°E -3.4 km	MSL	M, High phyllosilicate concentration Noachian deposits, No obvious volcanics	~75% stereo, 20% mono HiRISE	v preliminary	N	N, Non Go To	Dropped in favor of Mawrth 2 after 3rd Wkshp

Landing Sites (4)

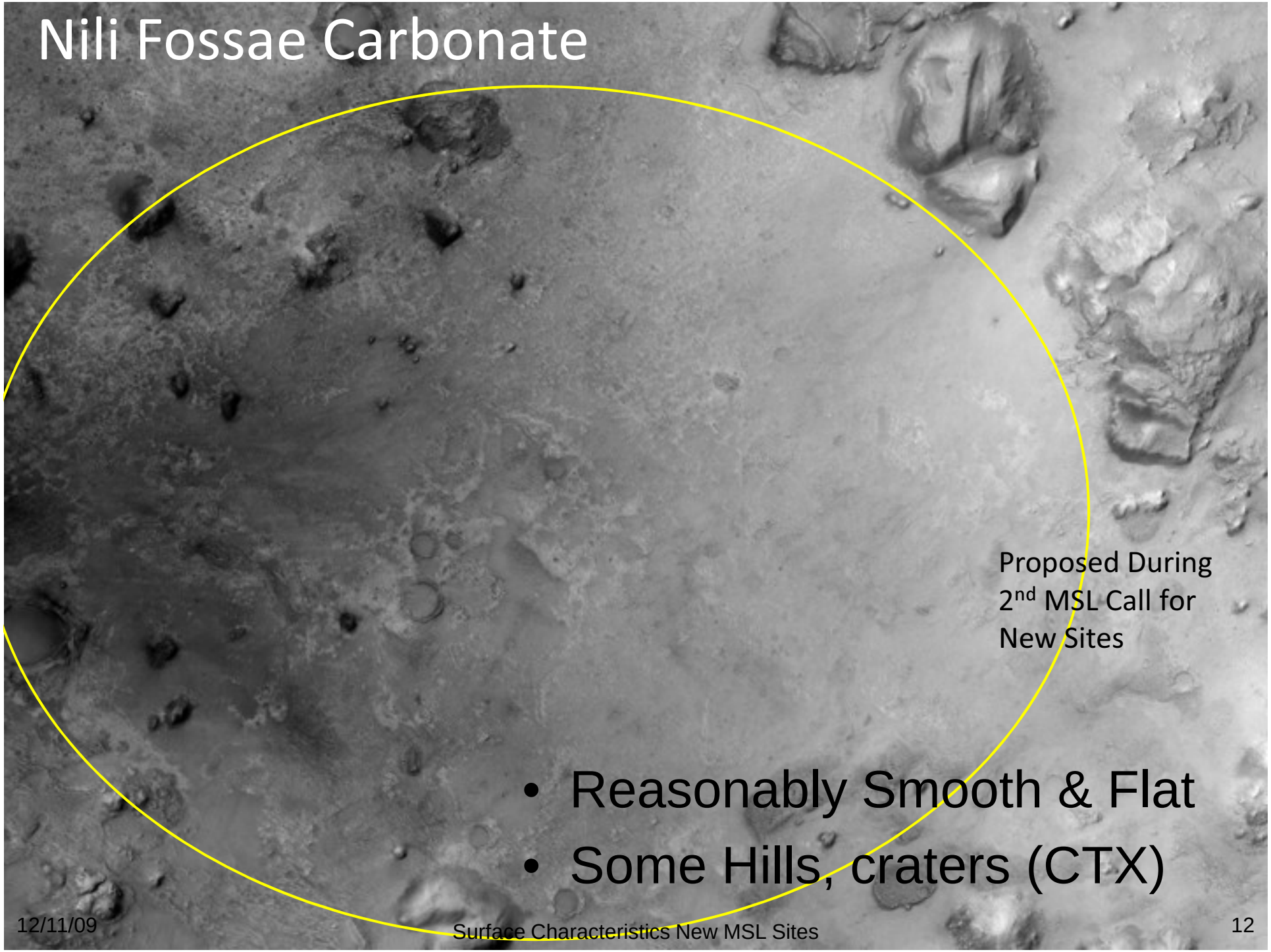
Very preliminary evaluation during MSL							

Ladon Basin 1) 18.8°S, 332.5°E 2) 20.5°S, 330.0°E 3) 20.2°S, 329.7°E -2.1 km	MSL, CDP VII	M, Chlorides in layered deposits W of ellipse, potential phyllosilicates, basalt plains	1) 0% 2) ~55% and 3) ~80% stereo HiRISE	v preliminary, 12/11/09	N	NE	2nd Call for New Sites, Not selected, Go To materials of interest W of ellipse (somewhat rough appearing)
Xanthe Terra Crater 2.3°N, 309°E -2.1 km	MSL	M, Fan in crater, amorphous silica, phyllosilicates in crater rim & channel feeding fan	~10% stereo HiRISE	v preliminary 12/11/09	Y	N, Not Go To	2nd Call for New Sites, Not selected, Rough terrain, large scarps, ripples & rocks
Evaluated during MER using MOC, few DEMs							
Meridiani Planum 2.0°S, 354.1°E -1.4 km	MER	L, Hematite concentration	~90% MOC, some DEMs	Intermediate, MER certification based on MOC	N	NA	Ballistic ellipse certified for MER
Elysium Planitia 11.9°N, 236.1°E -2.9 km	MER	L, Low wind site	<50% MOC, some DEMs	Intermediate, MER certification based on MOC	N	NA	Ballistic ellipse certified for MER
Isidis Planitia 11.9°N, 272.0°E -3.7 km	MER	L, just S or Libya Montes, material shed off	<50% MOC, some DEMs	Intermediate, MER certification based on MOC	N	NA	Ballistic ellipse certified for MER

Hazard Maps and TRN

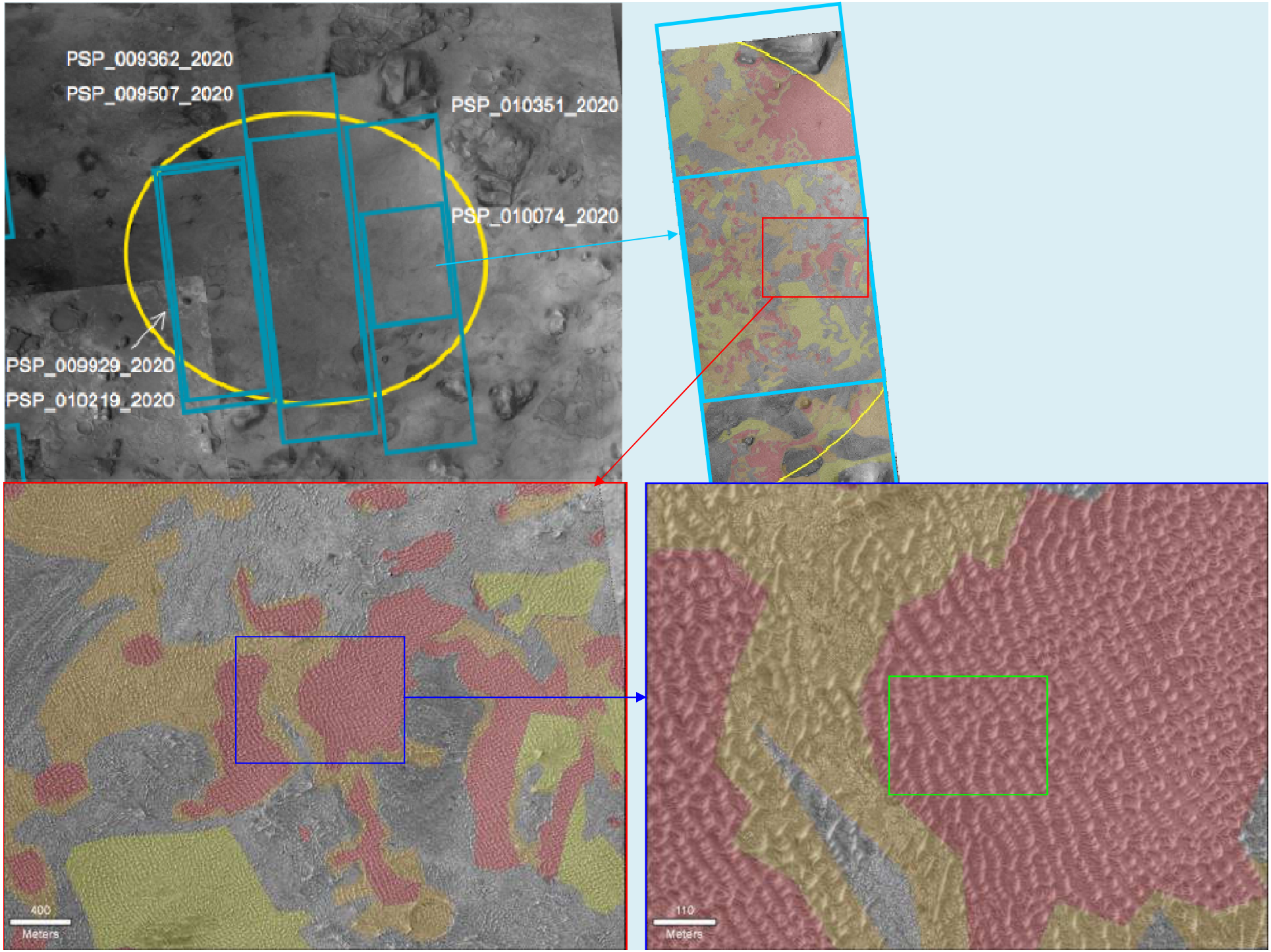
- Used Stereo Anaglyphs
  - Mapped Terrains and Relief
    - Similar Stereo Angle Anaglyphs with DEMs
- Topo Maps – Relief
  - MOLA, HRSC, CTX
  - Test against 100 m Relief within 1 km

Nili Fossae Carbonate



Proposed During 2nd MSL Call for New Sites

- Reasonably Smooth & Flat
- Some Hills, craters (CTX)


PSP_009362_2020
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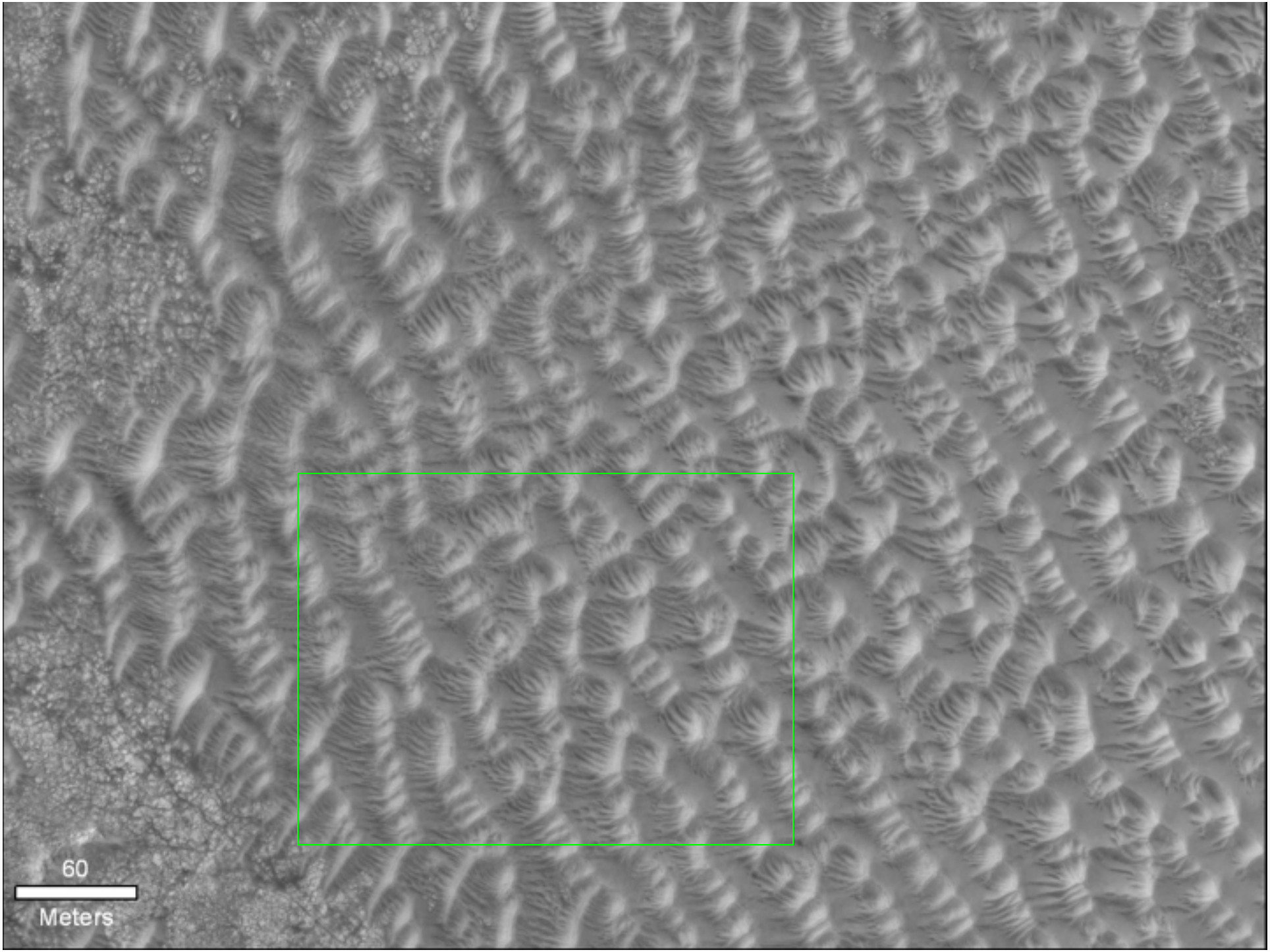
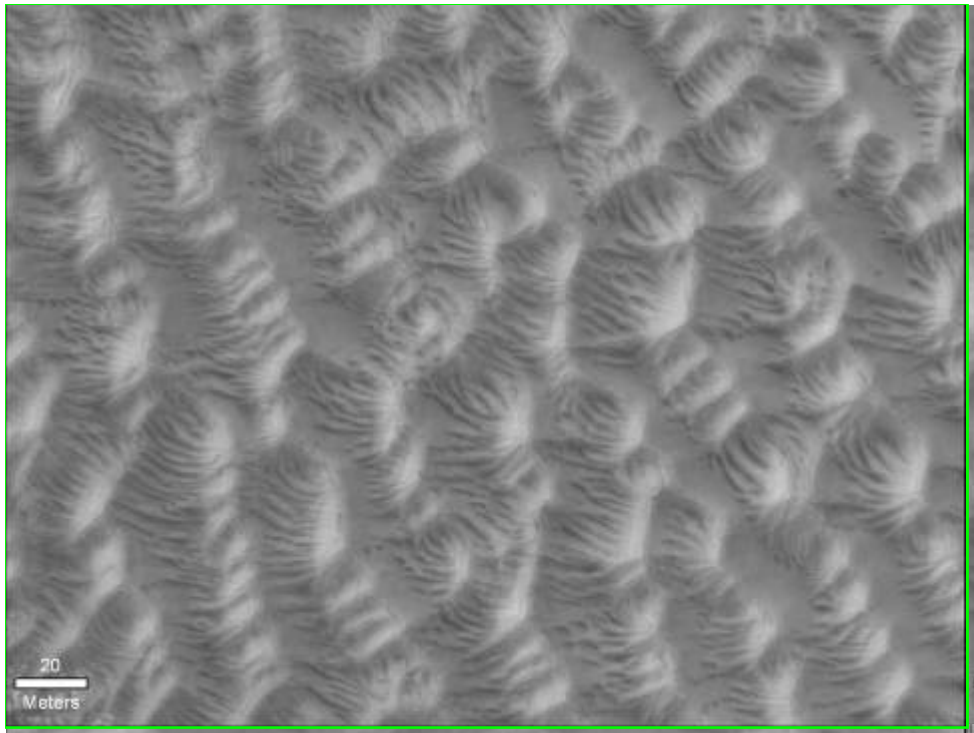
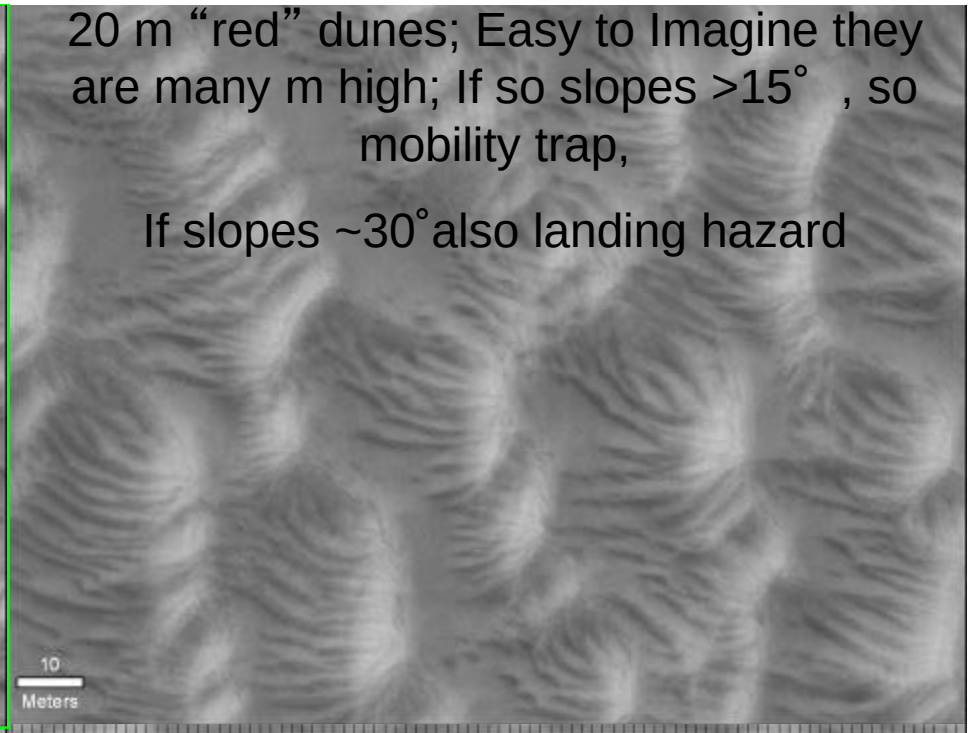
PSP_010351_2020
PSP_010074_2020
PSP_009929_2020
PSP_010219_2020
400
Meters
110
Meters

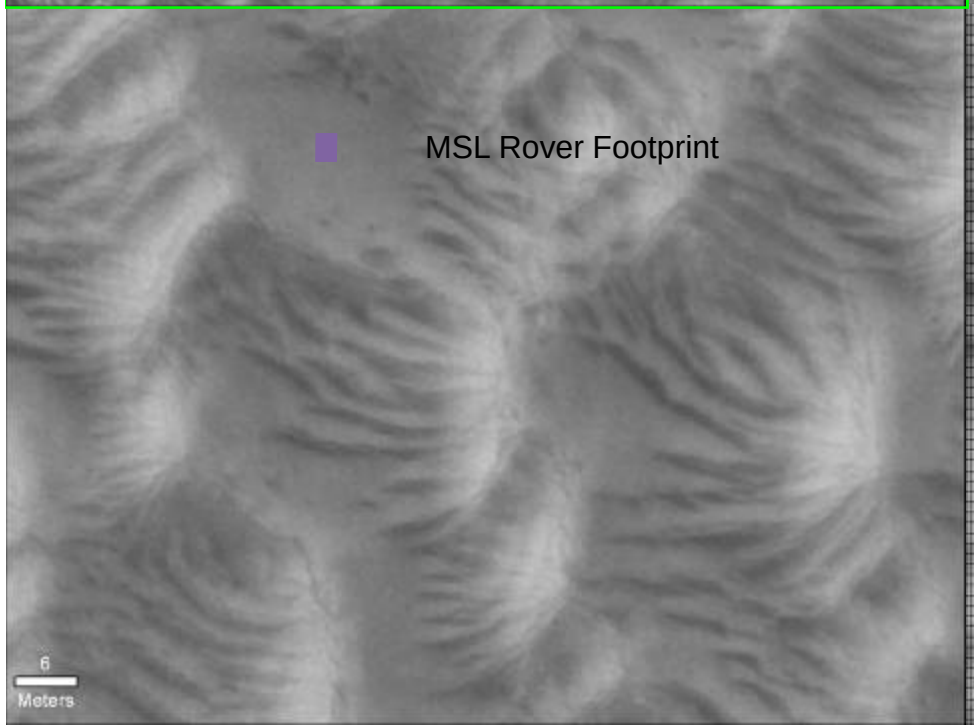

60
Meters

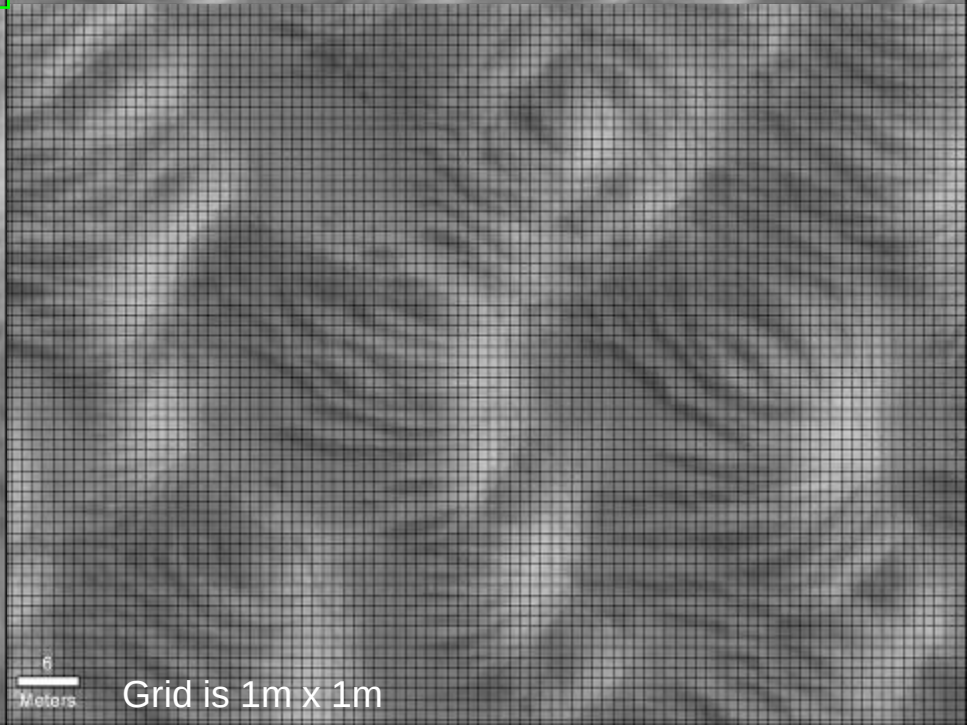


20 m “red” dunes; Easy to Imagine they are many m high; If so slopes >15˚ , so mobility trap,

If slopes ~30˚also landing hazard







Grid is 1m x 1m

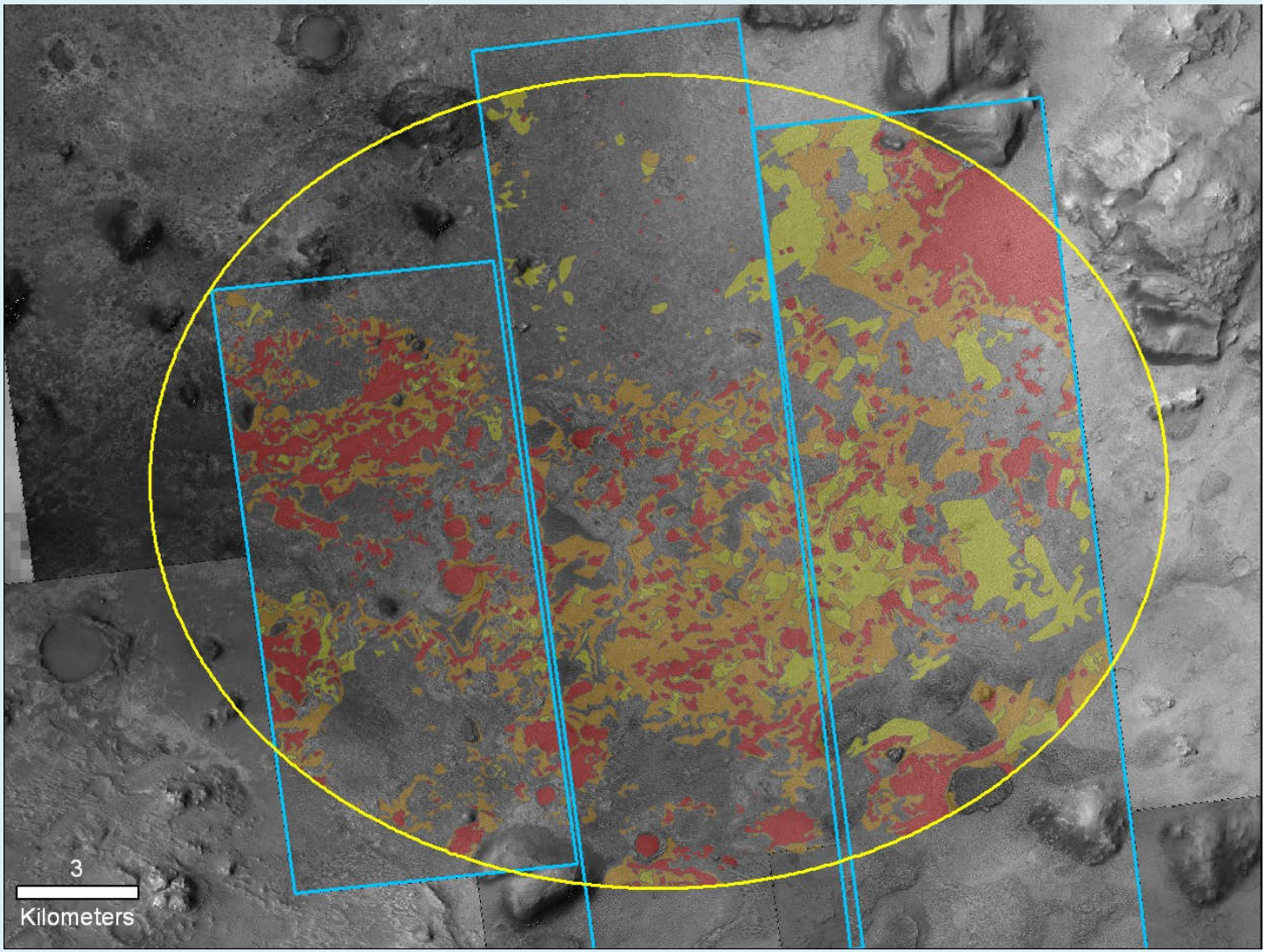
Nili Carbonate Ripple Density Map

Coverage in HiRISE:

Yellow = 9%
Orange = 22%
Red = 16%

Red are Inescapable Hazards

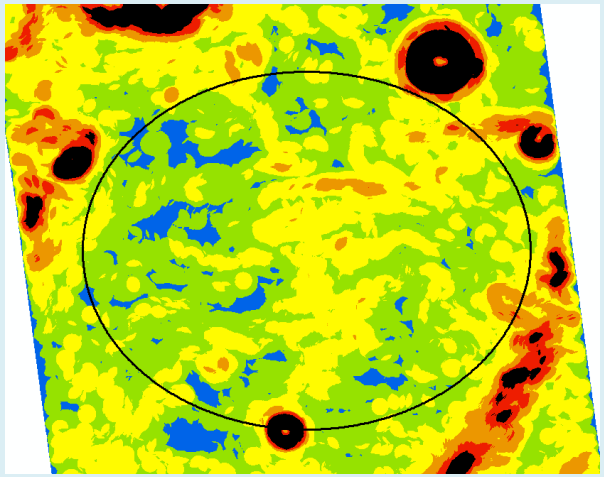
Need TRN to Avoid



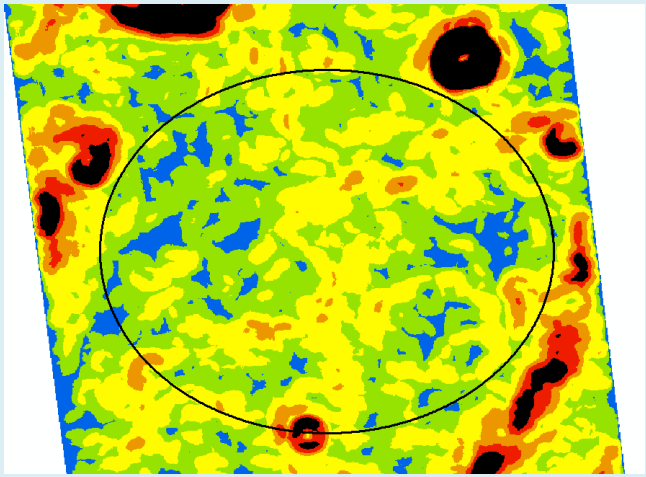
Red Throughout Ellipse

Nili Fossae

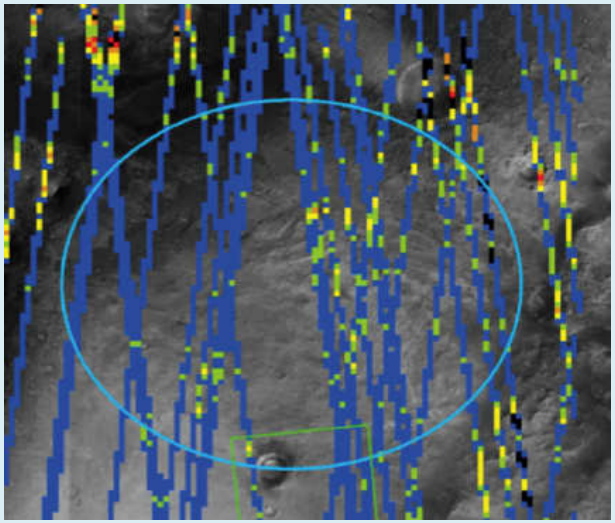
CTX: 5.5 m resolution



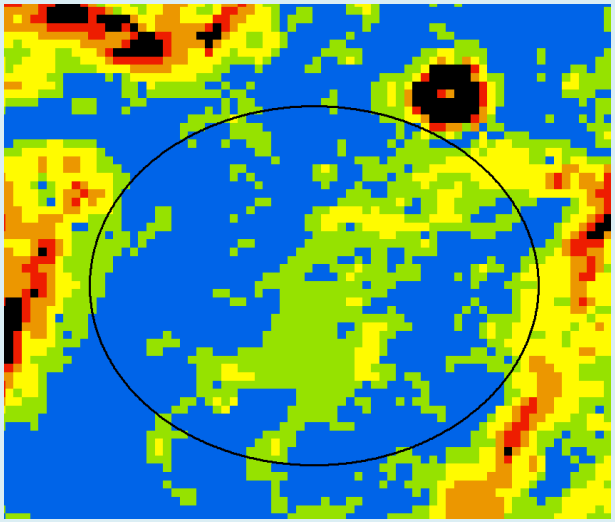
HRSC: 50 m resolution



MOLA Tracks



MOLA DEM



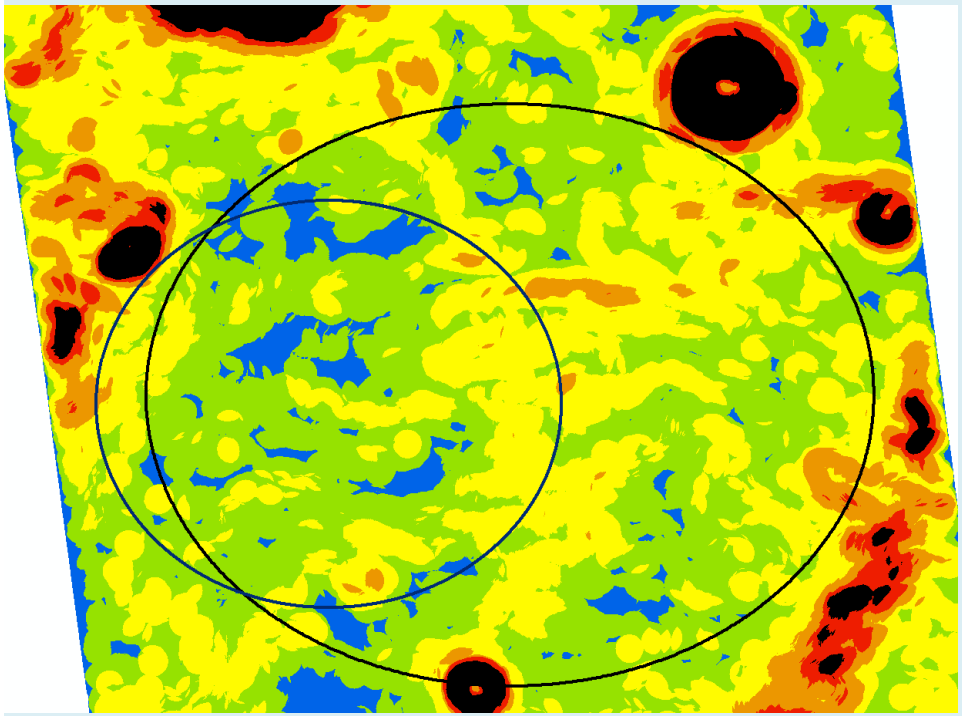
Relief Over 1 km (m)

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- 120 - 140
- 140 - 160
- 160 - 1,000

Nili Fossae

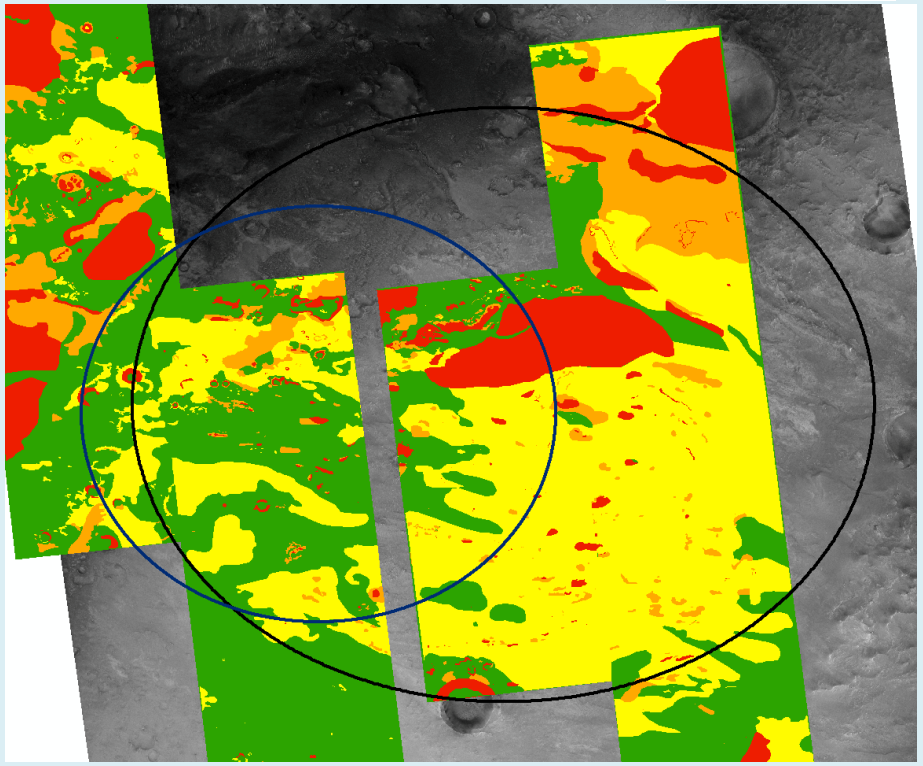
Relief Over 1 km (m)

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- 120 - 140
- 140 - 160
- 160 - 1,000



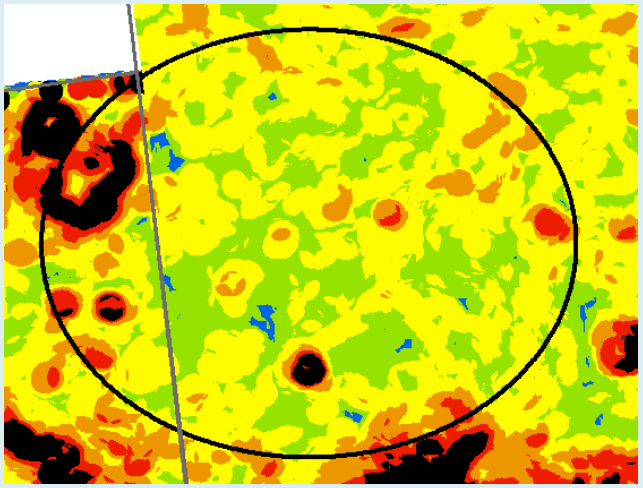
Hazards

- No Hazards
- Low
- Medium
- High

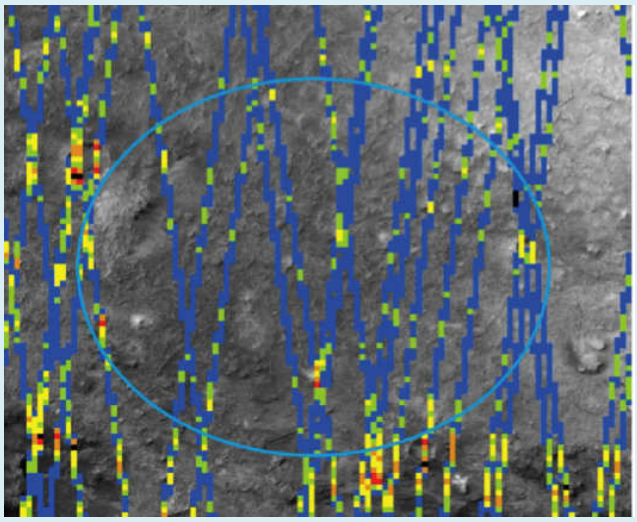


NE Syrtis

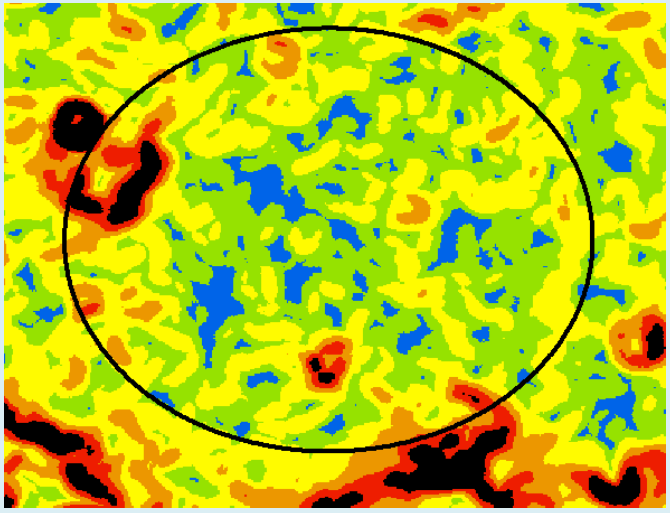
CTX: 5.5 m resolution



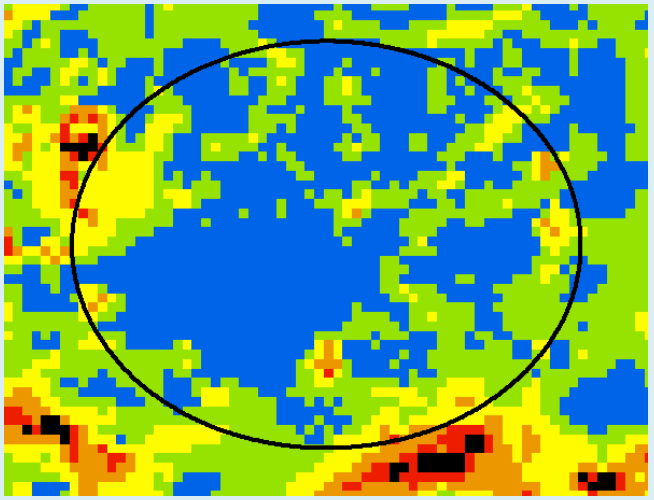
MOLA Tracks



HRSC: 75 m resolution



MOLA DEM



Relief Over 1 km (m)

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- 120 - 140
- 140 - 160
- 160 - 1,000

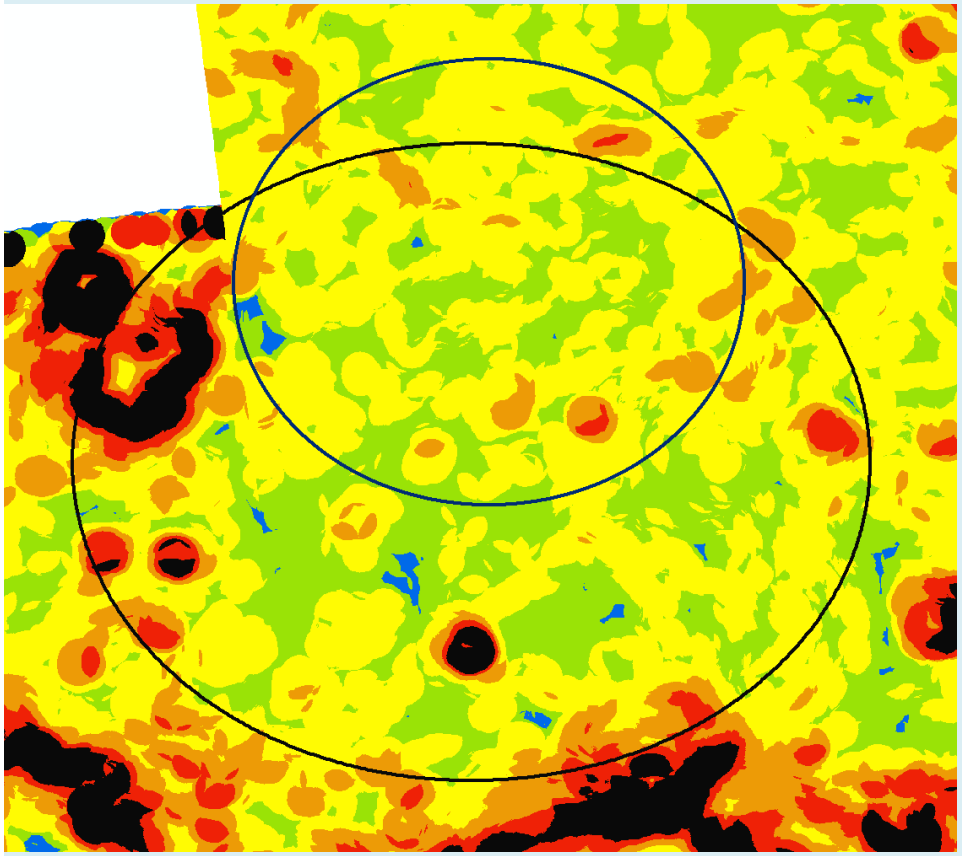
NE Syrtis

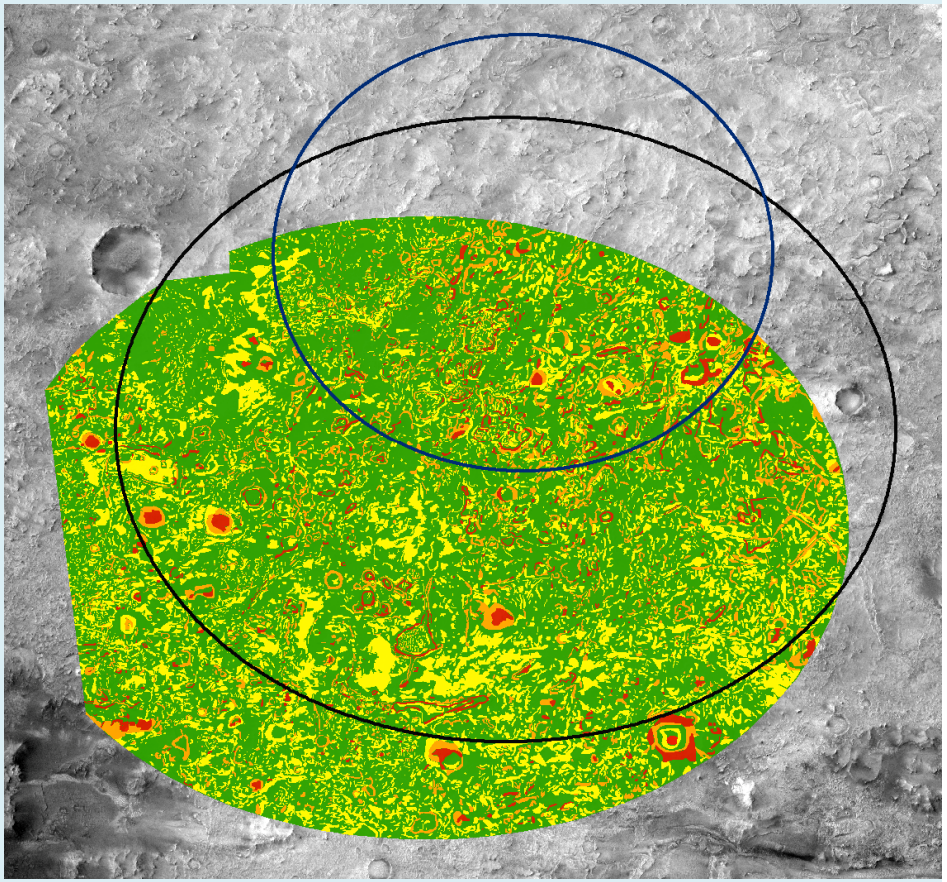
Relief Over 1 km (m)

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- 120 - 140
- 140 - 160
- 160 - 1,000

Hazards

- No Hazards
- Low
- Medium
- High





Criteria to Fill In During Workshop

Landing Site	Science Value Relative to 2020 Objectives	Need for Additional Imaging by Orbiters	Is Site Likely Land on or Go To?	Is Range Trigger Likely Needed for Access?	Does Range Trigger Reduce the Need for TRN?	Does Access Likely Require TRN?	If Go To, Would TRN Likely Make Land On?
NE Syrtis			Mostly Land On	No	Yes	Yes	Probably Improve Placement
Nili Fossae			Mostly Go To	No	Yes	Probably	No

Evaluation of Criteria

- Science Value Relative to 2020 Objectives
  - Astrobiologically Relevant Environment
  - Preserve Information to Understand Geological Record – Including Habitability and Preservation Potential
  - Preserve Materials Preserve Potential Biosignatures
  - Assemble Sample Cache – Include Igneous Rocks
  - Consistant with “Technology” Elements
- Need for Additional Imaging by Orbiters
  - Understanding of Site would benefit from Additional Orbital Imaging
- Is the Site Likely Land On or Go To?
  - Land adjacent and Drive or Land On Material of Prime Interest; 25x20 km Ellipse
- Is Range Trigger Likely Needed for Access?
  - Is Ellipse 16 km by 14 km Required to Land Safely (either Go To or Land On)?
- Does Range Trigger Reduce the Need for TRN?
  - Can Ellipse 16 km by 14 km Fit More Safely than 25 km by 20 km Ellipse?
- Does Access Likely Require TRN?
  - Are areas <110 m Radius that Violate Relief & Rock Constraints Surrounded by Areas >120 m radius that are Safe in Ellipse?
  - Constraints: Relief >100 m within 1 km; Rock Abundance >8%
- If Go To, Would TRN Make Land On?
  - Can Ellipse be Placed on Material of Prime Interest Safely with TRN?

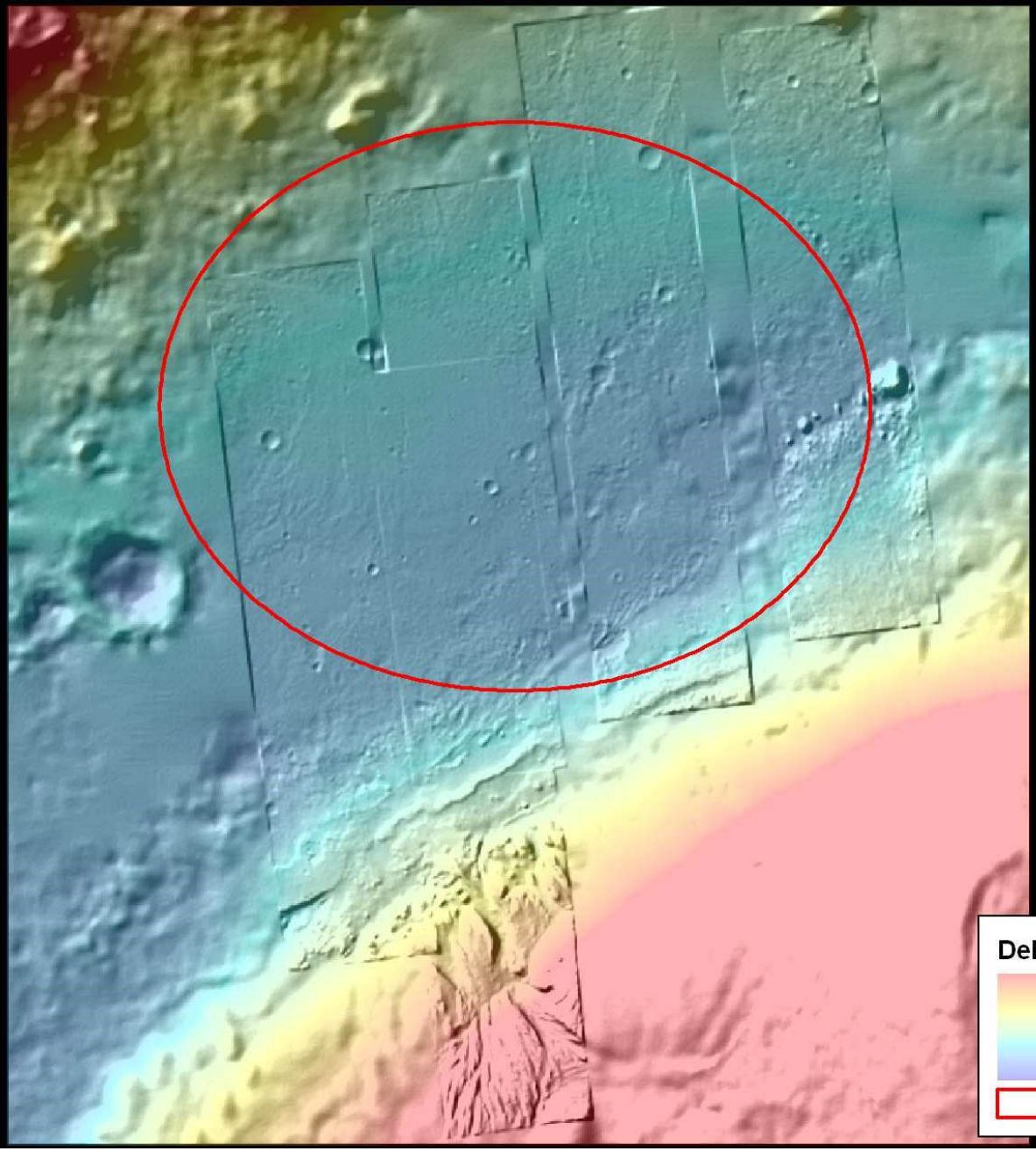
Imaging and Data Products Needed for Certification

Imaging and Data Products for Site Certification

Golombek et al. (2012) Selection of the Mars Science Laboratory Landing Site: Space Sci. Rev 170, 641-737

- DEMs & Slope Maps
  - HRSC, CTX, HiRISE
  - Nearly Complete Stereo Image Coverage - >90%
- Rock Maps – All Rocks >1.5 m Diameter
  - Rock Abundance and Size-Frequency Distribution
- Surface Material Properties
  - THEMIS Thermal Inertia
  - HiRISE Terrain Classification
- Traversability Maps
  - Slopes, Rocks and Material Properties
  - How Long Does it Take to Traverse based on Drive Mode Needed and Power Available
  - Are Areas of Interest Reachable
- Inescapable Hazard Maps
  - Slopes & Material Properties
  - Enclosed Depressions or Mesas that Can Land On but Not Escape
- Radar Reflectivity
  - Radar Backscatter & Cross Section; Reflectivity – Bulk Density

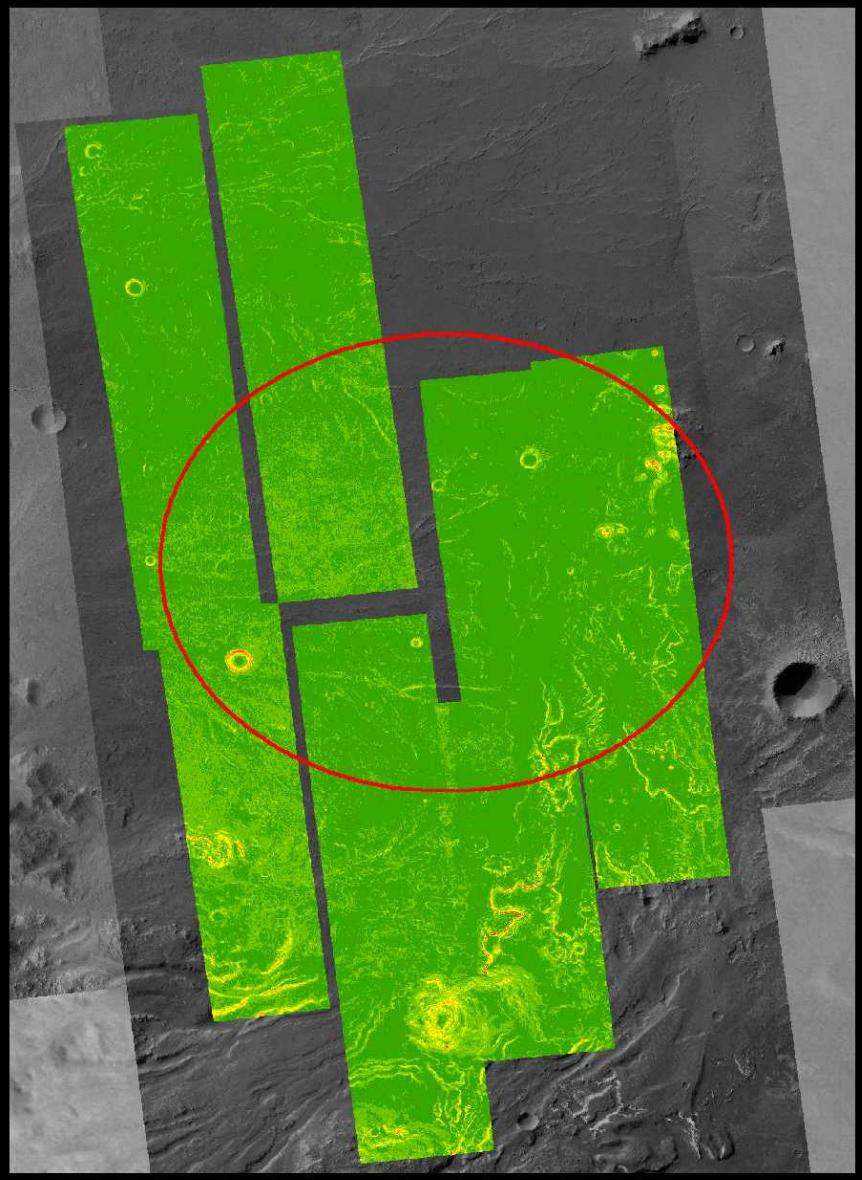
Gale: Ellipsoid Elevation



Hierarchally Co-registered MOLA, HRSC, CTX, HiRISE DEMs

Golombek et al. (2012)

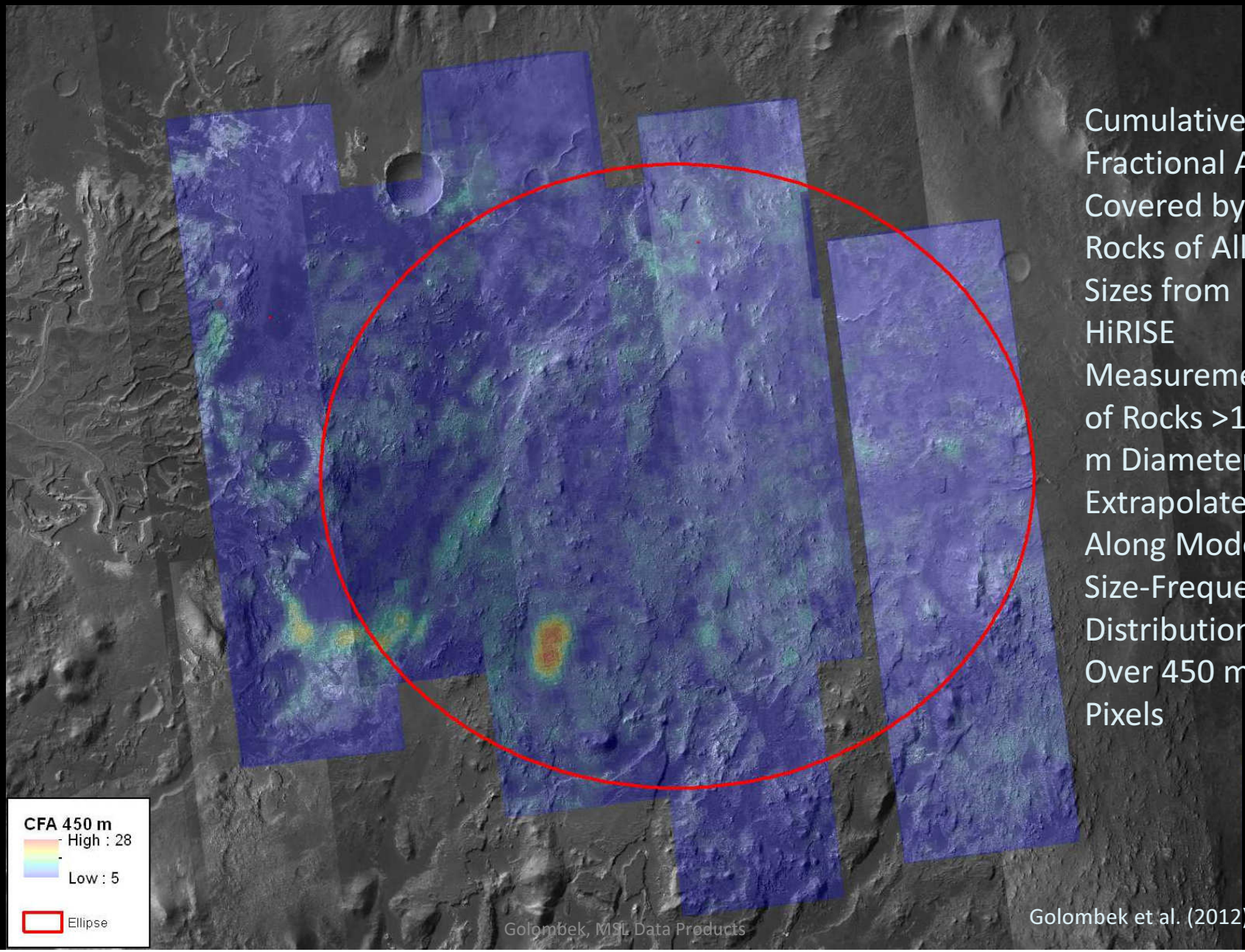
Holden Slopes (1m)



Slopes (1m)
- 0 -< 5
- 5 - <10
- 10 - <15
- 15 - <20
- 20 - <25
- 25 - <30
- 30 - <90

From 1 m Elevation Posting HiRISE DEMs

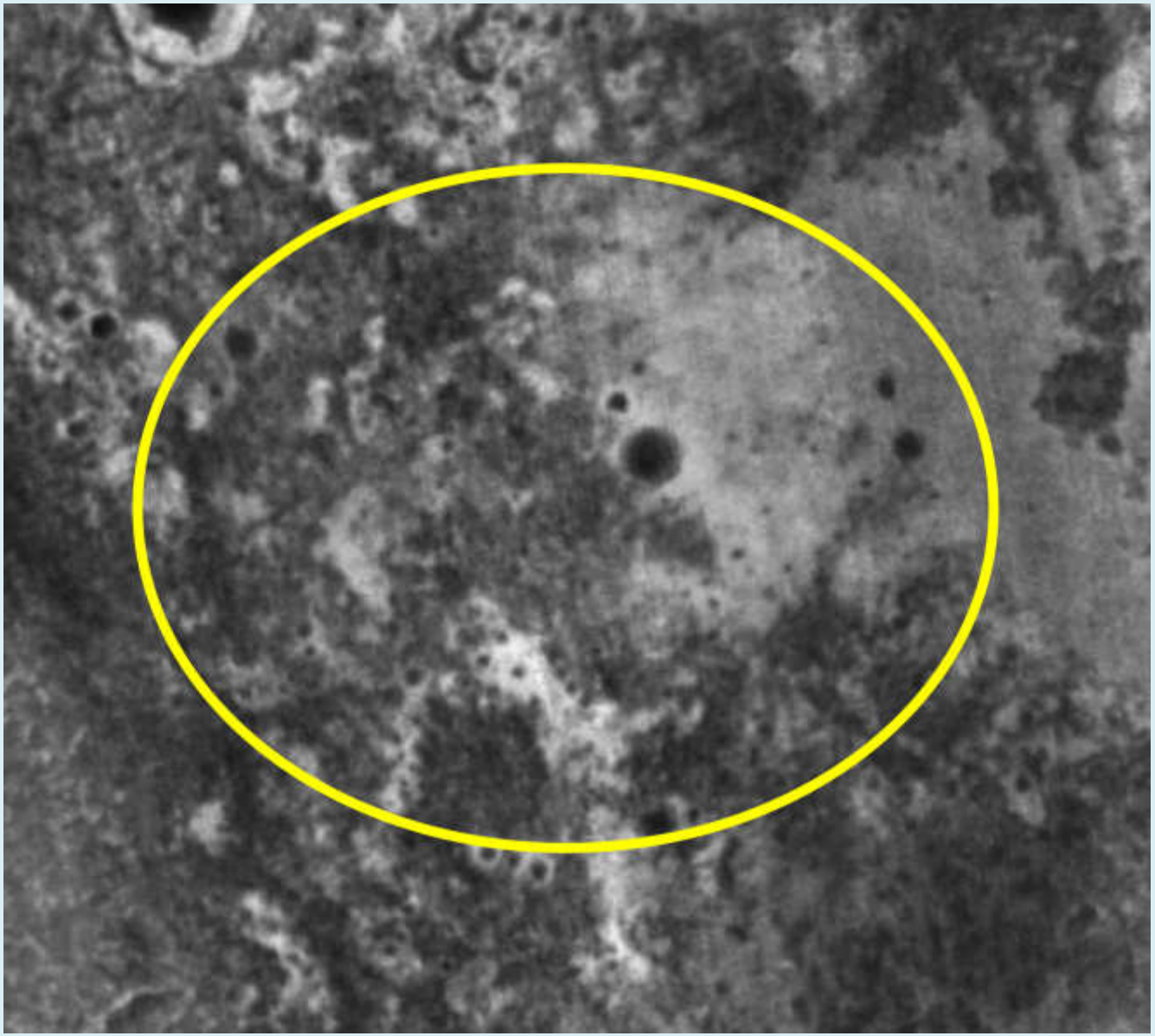
Eberswalde CFA 450 m



Cumulative Fractional Area Covered by Rocks of All Sizes from HiRISE Measurements of Rocks >1.5 m Diameter Extrapolated Along Model Size-Frequency Distributions Over 450 m Pixels

Golombek et al. (2012)

Mawrth Vallis



High Inertia Outcrop

Low Inertia Sediment

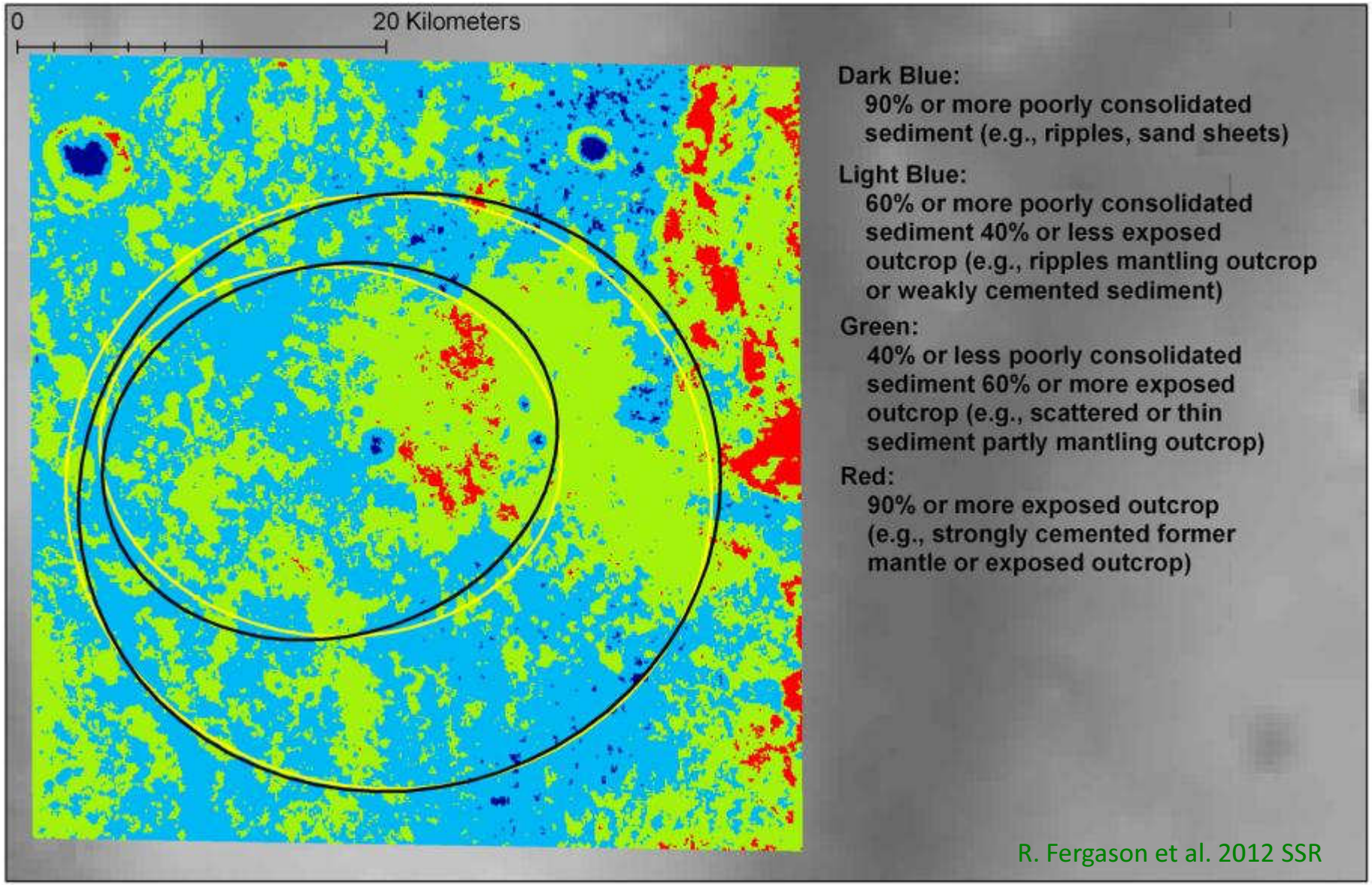
Intermediate-Mixes

THEMIS
Thermal Inertia
J m^{-2} K^{-1} $s^{-1/2}$

240 495

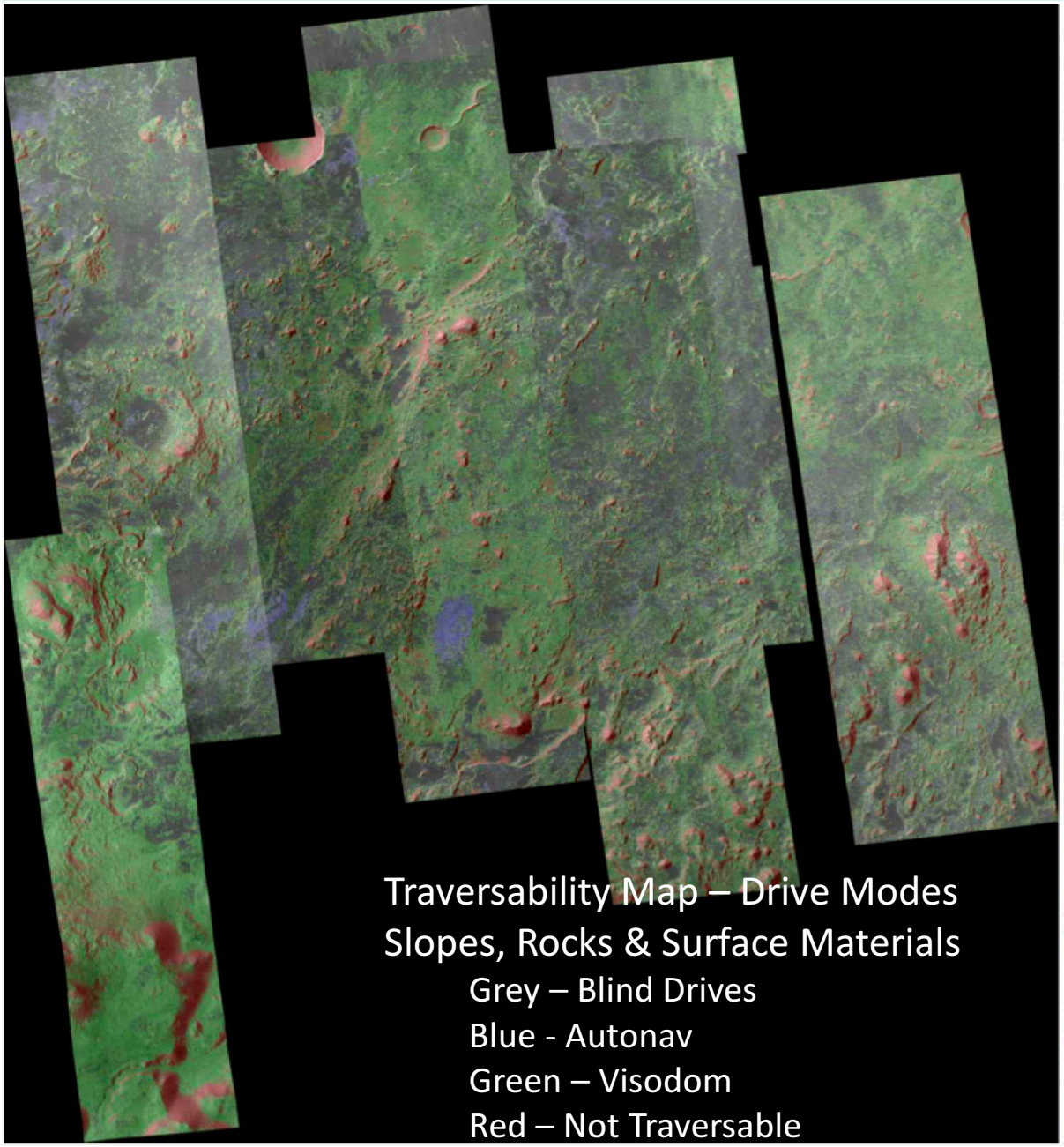
R. Fergason et al. 2012 SSR

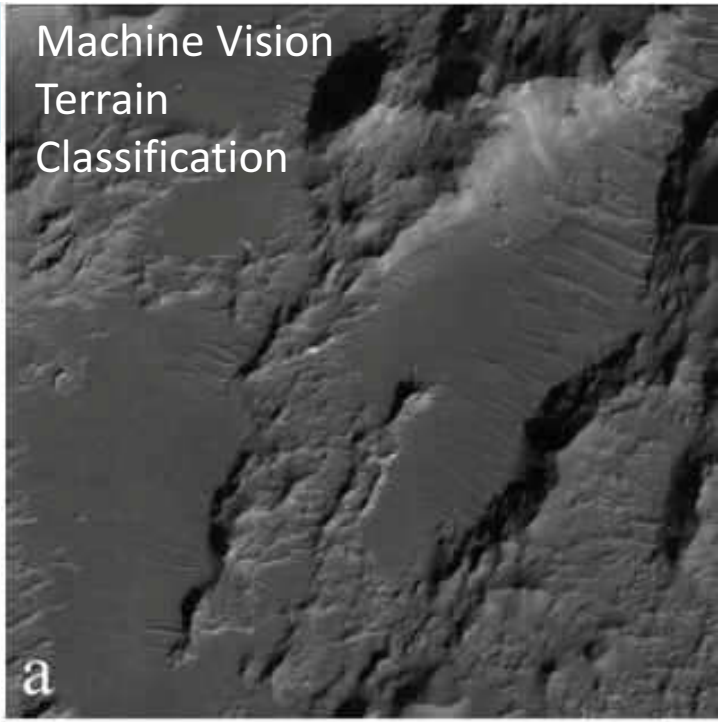
Mawrth Vallis
Site 2: 23.99 N, 341.04 E (SH: 23.95 N, 341.11 E)
Center Elevation Site 2: -2246 m (SH: -2254 m)

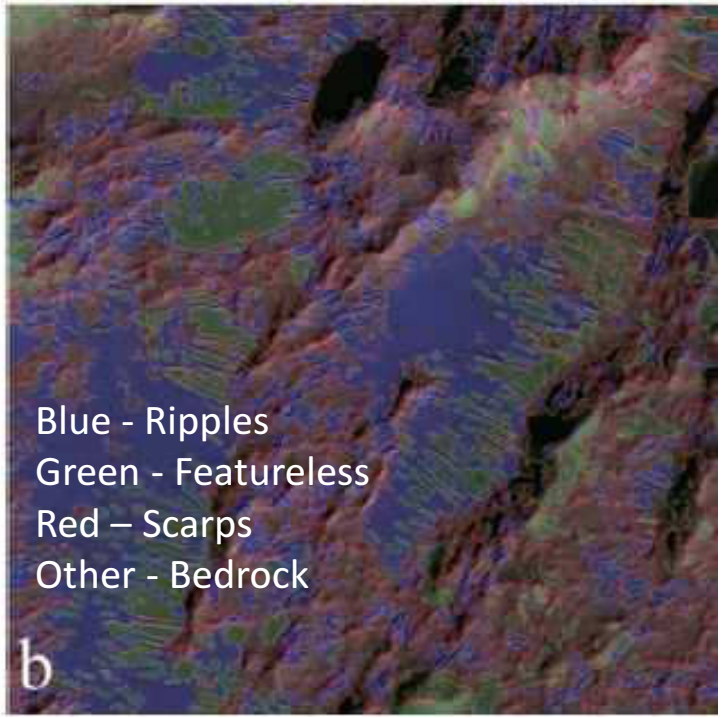


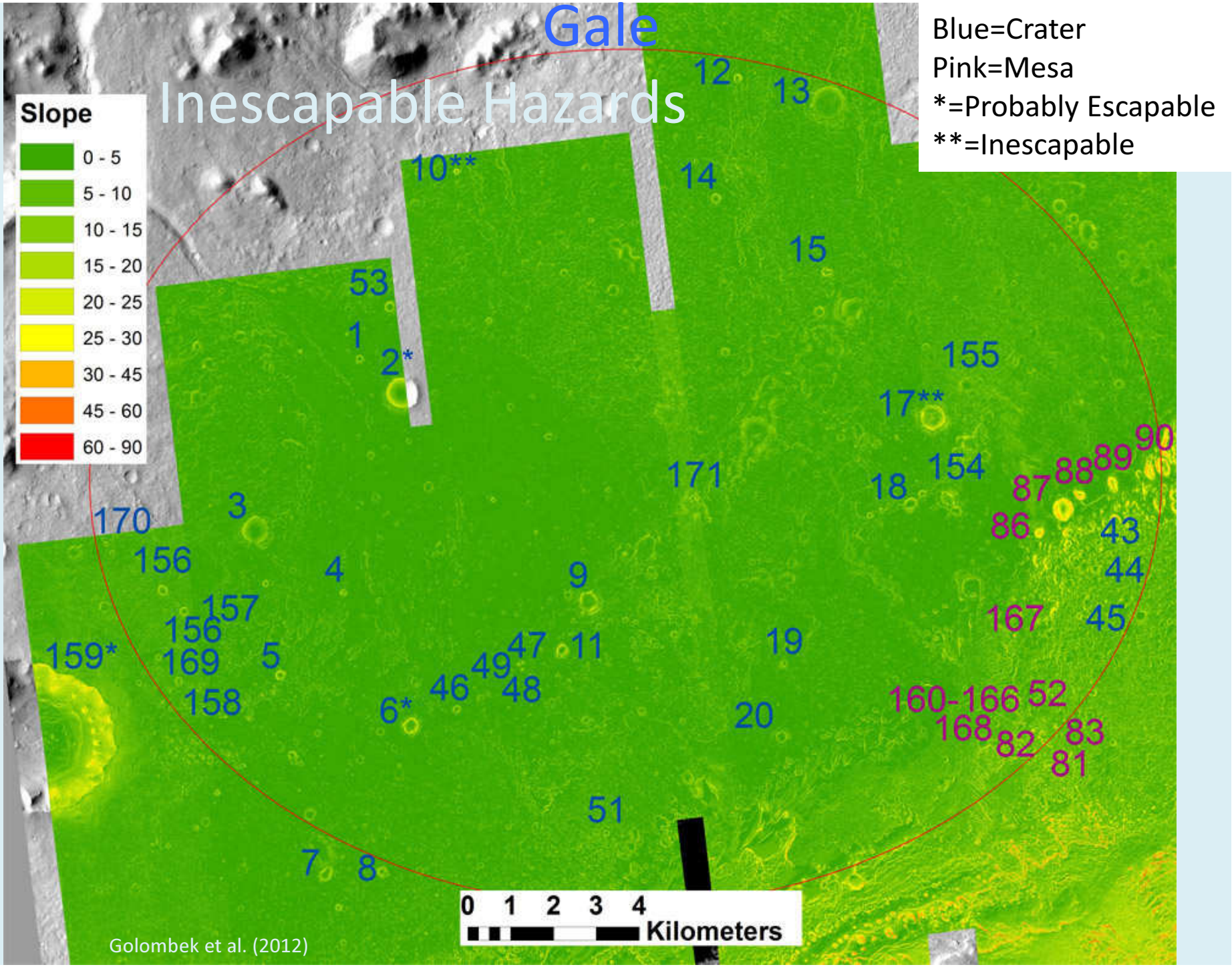
R. Fergason et al. 2012 SSR

Eberswalde Traversability





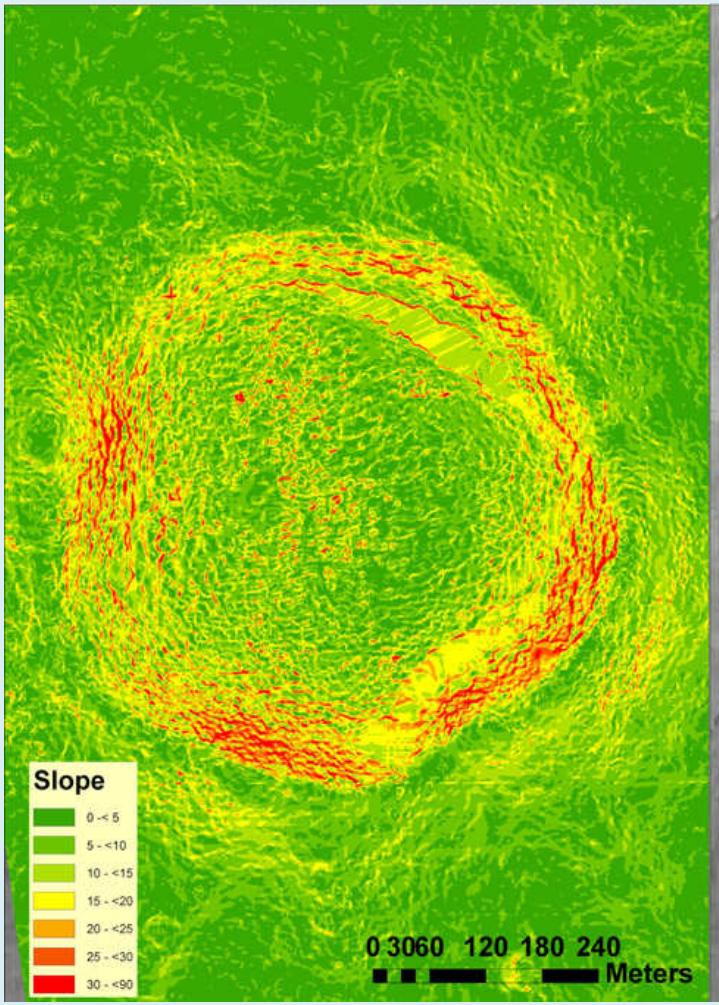


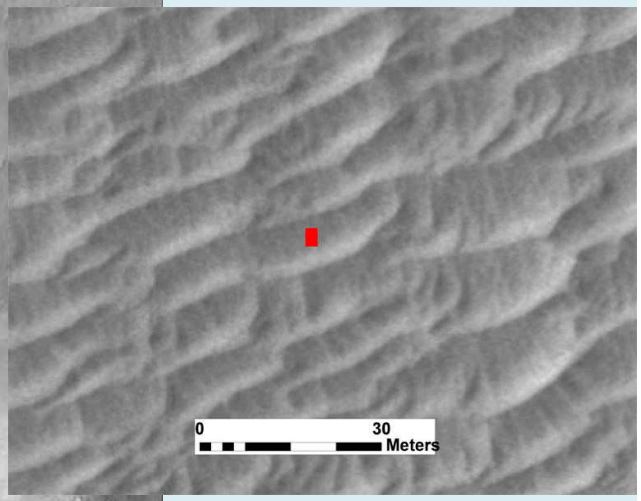

Gale
Inescapable Hazards
Blue=Crater
Pink=Mesa
*=Probably Escapable
**=Inescapable
Slope
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 45
45 - 60
60 - 90
12
13
10**
14
15
53
1
2*
155
17**
171
18
154
87
88
89
90
86
43
44
3
170
156
4
9
157
156
167
45
159*
169
5
47
11
19
49
46
48
160-166
52
158
6*
20
168
82
83
81
51
7
8
0 1 2 3 4
Kilometers
Golombek et al. (2012)

Gale ID. 17** Inescapable Hazard

- Crater, 400 m diameter
- 15 to 30° Slopes
- Loose material on interior slopes, bedforms on floor
- 232084 m^2
- 137.548, -4.463

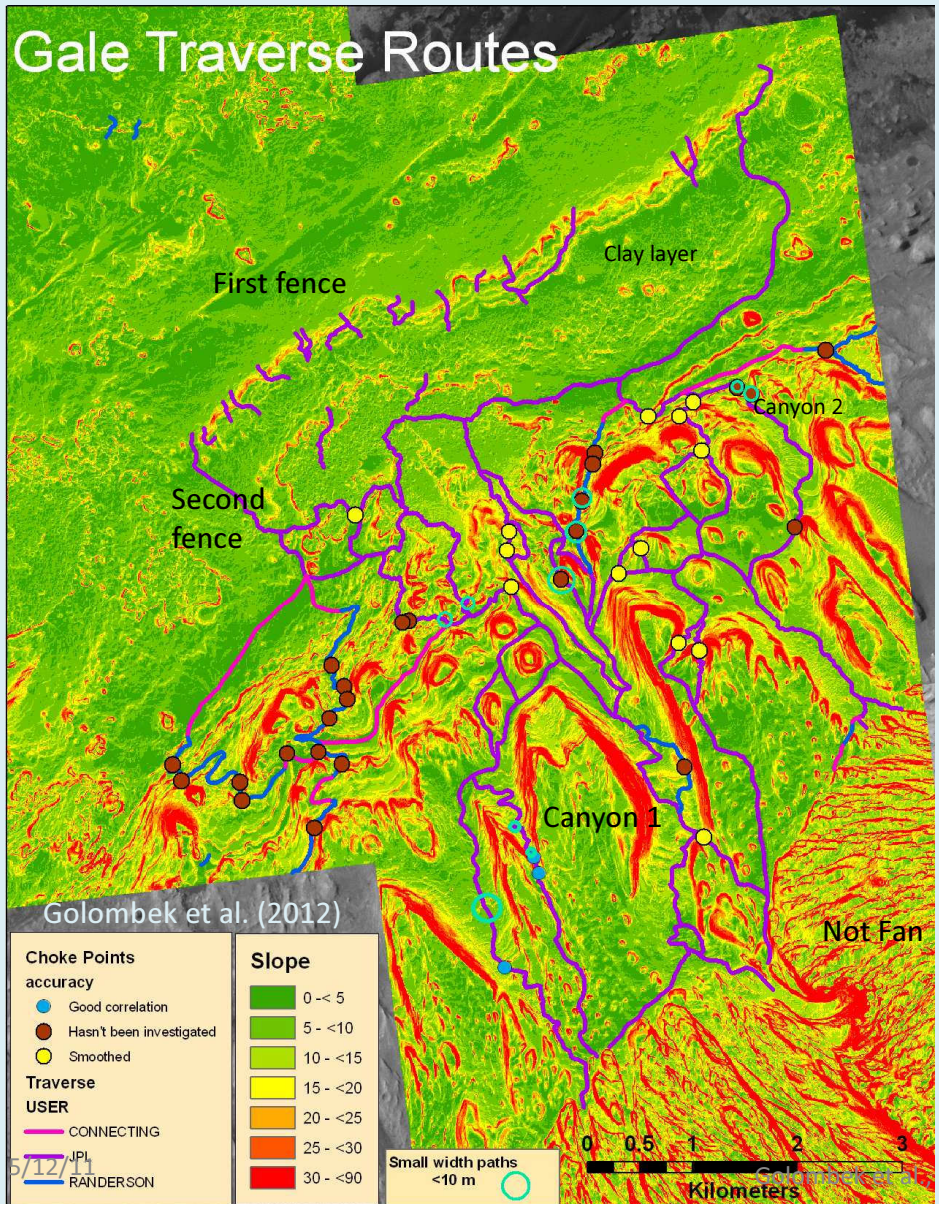
- Inescapable
- Coverage shows >15 ° slopes and loose material around entire crater interior
- No obvious egress route
- Bedforms are likely traversable

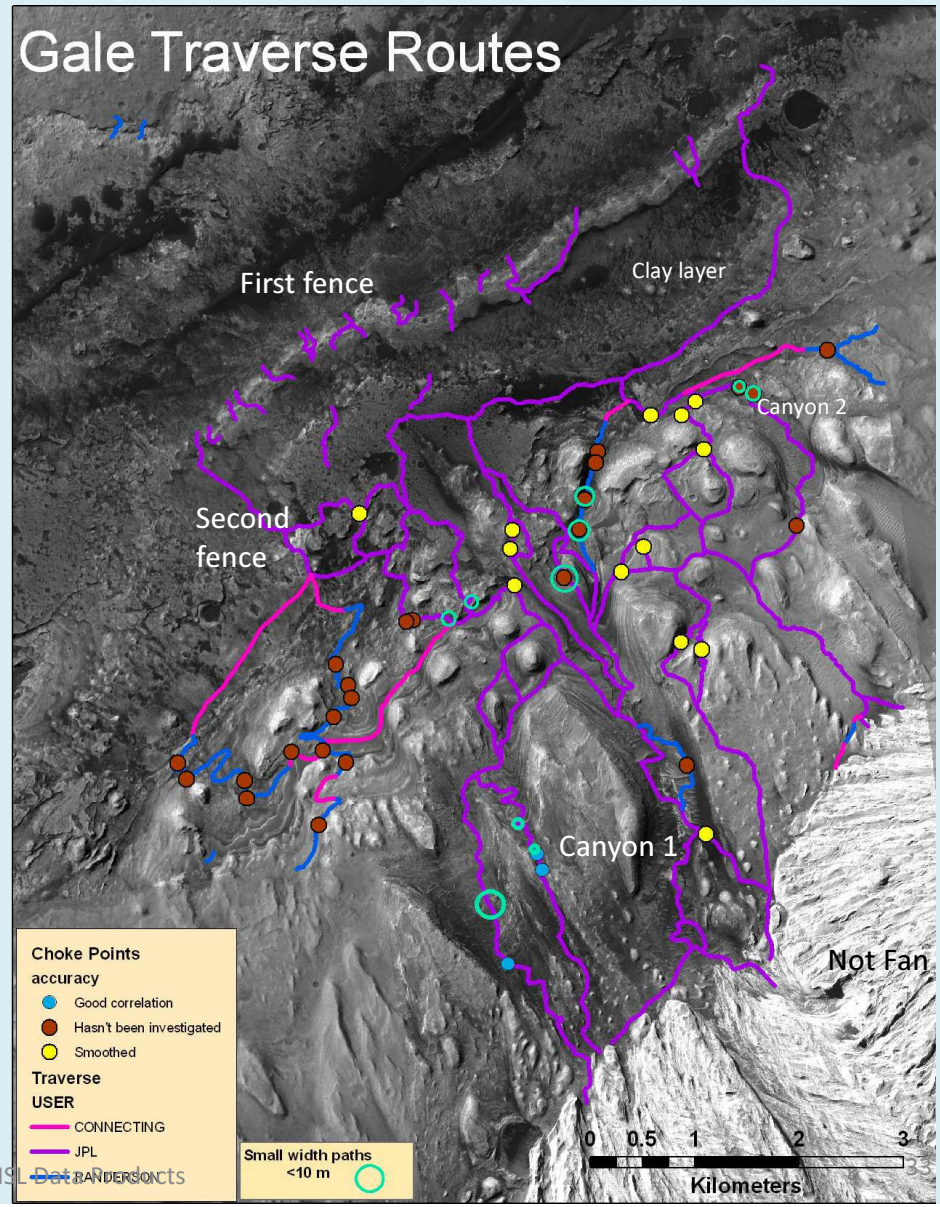




Golombek et al. (2012)

Gale Traverse Routes





So Let the 2020 Mars Rover Landing Site Selection Adventure Begin